AN OPTIMAL IRRIGATION WATER ALLOCATION MODEL: MANAGEMENT AND PRICING POLICY IMPLICATIONS FOR THE JORDAN VALLEY

by

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ABBREVIATIONS

ACC	Agricultural Credit Corporation, Jordan
AMPCO	Agricultural Marketing & Processing Company, Jordan
b.c.m	Billion cubic meters
CBJ	Central Bank of Jordan, Jordan
CM	Central Market, Jordan
CM	Cubic Meters
DOM	Department of Meteorology, Jordan
DOS	Department of Statistics, Jordan
Du	Dunum
EU	European United
EFTA	European Free Trade Agreements
FAO	Food and Agriculture Organization
FC	Fixed Costs
FTA	Free Trade Agreements
GAFTA	Greater Arab Free Trade Area
GDP	Gross Domestic Product
GOJ	Government of Jordan
GM	Gross Margin
G.R	Growth Rate
Ha	Hectare
ICARDA	International Center for Agricultural Research in Dry Areas
IMF	International Monetary Fund
JD	Jordan Dinar; Jordanian Currency
JV	Jordan Valley, Jordan
JVA	Jordan Valley Authority, Jordan

JRV	Jordan Rift Valley, Jordan
KAC	King Abdullah Canal, Jordan
Km	Kilometer
KTD	King-Talal Dam, Jordan
M or m	Meter
m^3	Cubic Meters
MCM	Million Cubic Meters
MOA	Ministry of Agriculture, Jordan
M&I	Municipal and Industrial
mm	Millimeter
MOP	Ministry of Planning, Jordan
MWI	Ministry of Water and Irrigation, Jordan
NGO	Non governmental organization
O&M	Operation and Maintenance
RHS	Right Hand Side
Sq.Km	Square Kilometers
TC	Total Costs
US - AID	United State of America AID
VC	Variable Costs
WB	World Bank
WHO	World Health Organization
WMIS	Water Management Information System, Jordan
WTO	World Trade Organization

MEASURES

Dunum	0.1 hectare (1,000 square meters)
1 Ha	10000 m^2
1 Fills	0.001 Jordan Dinar

1 Ton	1000 KG

EXCHANGE RATE

Jordan Dinar JD	1 $ = 0.709 Jordan Dinar for the year 2001/2002

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SATU MODEL PERUNTUKAN PENGAIRAN AIR YANG OPTIMUM: IMPLIKASI TERHADAP PENGURUSAN DAN POLISI - POLISI HARGA UNTUK LEMBAH JORDAN

ABSTRAK

Kekurangan air merupakan satu masalah serius di kebanyakan negara di Asia Barat. Jordan menggunakan lebih kurang 70 peratus daripada sumber airnya untuk tujuan pengairan.

Objektif utama kajian ini adalah untuk membangun satu model pengurusan bagi mengoptimumkan penggunaan air untuk tujuan pengairan di Lembah Jordan. Kajian ini akan menghsilkan satu pendekatan praktikal untuk tujuan tersebut dengan membangun satu model optimum pemprograman linear untuk tujuan menganalisis peruntukan air pengairan daripada aspek kuantiti, kualiti, tempoh masa, harga dan dasar harga dan kesannya ke atas pendapatan dan pengeluaran hasil pertanian.

Keluk permintaan optimum air serta keluk permintaan *'derived'* untuk keluasan ditanam, kuantiti buruh pertanian dan baja mengikut harga air yang berbeza boleh dianggarkan daripada model ini. Ini membolehkan keanjalan permintaan untuk air dan untuk segala sumber terhad lain dianggar dengan menggunakan model yang sama. Corak tanaman optimal di Lembah Jordan dan di daerah-daerahnya boleh juga dihasilkan. Jadual pengguaan air secara optimal boleh diperolehi daripada model dan agihan boleh dibuat mengikut bulan dan mengikut keperluan kawasan yang di tanam. Hasil kajian menunjukkan penggunaan harga air sebagai satu alat dasar adalah amat berkesan dalam pengurusan sumber air oleh institusi pengurusan air yang ada di Lembah Jordan.

Keluk permintaan optimum air membolehkan anggaran permintaan dibuat dengan harga yang berlainan dan dengan kombinasis akativiti optimal pada setiap tahap harga. Keluk permintan air optimum boleh juga dianggarkan bagi setiap daerah dan bagi keseluruhan kawasan berasaskan model ini. Kesemua anggaran didapati sama dengan anggaran keanjalan permintaan air yang dibuat serta menggambarkan penggunaan sebenar air mengikut harga yang telah ditetapkan.

Hasil kajian menunjukkan keluasan kawasan tanaman optimal adalah lebih kurang 211 ribu danum atau lebih kurang 69 peratus daripada keseluruhan kawasan yang ada di Lembah Jordan. Kuantiti air untuk saliran yang ada hanya mencukupi untuk 82 peratus daripada kawasan di Lembah Jordan. Corak tanaman optimal ini akan menghasilkan pendapatan sebanyak 37.97 juta Dinar Jordan (JD) dengan harga air semasa 0.025 JD/CM. Jumlah pendapatan akan berkurangan jika harga air dinaikkan. Keanjalan harga air adalah -0.04 di Lembah Jordan pada harga air 0.025 JD/CM. Mengikut jadual air untuk pengairan semasa, air akan berlebihan pada bulan tertentu dan berkurangan pada bulan lain.

Harga air pada kadar 0.70 JD/CM adalah tahap pulang modal (break - even) untuk tanaman sayuran tetapi tahap kerugian bagi tanaman lain. Pada harga 0.025 JD/CM, keuntungan bagi setiap dunum adalah 180.1 JD dan bagi setiap meter padu adalah 0.177 JD. Kajian mencadangkan harga air semasa dinaikkan daripada 0.025 JD/CM kepada 0.05 JD/CM untuk mengurangkan penggunaan air tanpa memberi kesan kepada kawasan yang ditanam, penggunaan buruh dan baja serta menjamin kestabilan margin kasar pendapatan.

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ABSTRACT

Water shortage is a serious problem in most countries in the Middle East. In Jordan, Irrigation water consumes about 70 percent of the available fresh water resources.

The main objective of this study is to develop a management model for optimal use of irrigation water in the Jordan Valley. The study presents a practical approach for the purpose by building a linear programming optimization model for analyzing allocation of irrigation water in quantities, qualities, timing, prices and pricing policies; and their impact on agricultural production and income.

The optimal water demand curves as well as the derived demand curves for planted area, agricultural labor and fertilizers according to the different water prices can be derived from this model. Consequently, demand elasticities can also be estimated for water and for the other constraints. Optimal cropping pattern in the Jordan Valley and its districts are also generated from the model. The optimal water demand schedule is obtained by the model and distributed according to the months and the needs of the planted areas. The results shows the effectiveness of the use of pricing mechanism as a policy tool in dealing with water in irrigated agriculture under the current water management institution in the Jordan valley.

The optimal demand curves allow to quantitatively estimate the demand for water at various prices and on the optimal mix of activities for every water price. Optimal demand curves can also be obtained by the model for both districts and for entire

region. They appear to be agreement with estimates of elasticity of water demand as well as reflect actual water usage at suggested prices reasonably closely.

The results show that the optimal planted area in the Jordan Valley is about 211 thousand dunum which is about 69 percent of the total available area in the Jordan Valley. The limited quantity of irrigation water covers only 82 percent of the total area in the Jordan Valley. The optimal cropping pattern would generate 37.97 Million Jordanian Dinar (JD) at the prevailing water price of 0.025 JD/CM. A reduction in the total net income occurs when the prices of water increased. The price elasticity of water demand is – 0.04 in the Jordan Valley at the prevailing water price of 0.025 JD/CM. The current schedule of irrigation water shows that some months have an excess of water while others have a shortage.

The water price of 0.70 JD/CM represents the break-even price for vegetables while most of the crops experience losses. At the prevailing water price of 0.025 JD/CM, the profitability of one dunum is 180.1 JD, and of one cubic meter is 0.177 JD. It has been recommended that the current price of water be increased from 0.025 JD/CM to 0.05 JD/CM, in order to reduce irrigation water consumption without affecting the planted area or the agricultural labor or the agricultural fertilizers and to keep gross margin stable.

CHAPTER ONE

INTRODUCTION

Jordan is about 89 320 square kilometers in area, located between the latitudes of 29.0 and 33.5 degrees north, and the longitudes of 35.0 to 39.5 degrees east. It lies within the semi-arid climatic zone and has a typical Mediterranean short, rainy winter and a long, dry summer. Annual precipitation varies with location and topography, but ranges from 50 mm in the desert to 600 mm in the northwest highlands. Jordan is one of the most water scarce countries in the world.

The climate is generally arid, with more than 90 percent of Jordan's total area receiving less than 200 millimeters rainfall per year and more than 70 percent of the country receiving less than 100 millimeters of precipitation on a year. Only around 2 percent of the land area, located in the north-western highlands has an annual precipitation exceeding 300 millimeters, though the northern highlands may receive as much as 600 millimeters. About 5.5 percent of Jordan's area is considered dry land with annual rainfall ranging from 200 to 300 millimeters, as shown in Table 1.1, (Haddad, 1991). The pattern of rainfall is characterized by an uneven distribution over the various regions, and strong fluctuation from year to year in terms of quantity and timing.

There are three quite distinct physiographic regions in Jordan with unique climates: The Central Highlands make up the hilly to mountainous region of the country, which ranges from 600 to 1600 meters in elevation, and provides the majority of Jordan’s arable land.

It is the region that receives by far the most rainfall at an average of 582 mm per year. The capital city of Amman is located in this region, and average temperatures in Amman range from around 8 degrees C°. in January, to 25 degrees C°. in July. The central highlands produce fruits, vegetables and cereal grains.

The Rift Valley runs along the entire length of Jordan's western border, and descends to 400 meters below sea level at the Dead Sea. The soil is fertile in the Rift Valley, and the zone is relatively rich in subsurface water resources, with average temperatures ranging from 14.9 degrees C°. in January to 31.3 degrees C°. In July, (DOM, 1999), the agricultural sector is able to produce three crops per year, employing the latest techniques in water conservation. It's about 50 percent of the total production of fruits and vegetables in this region, and exported to the Gulf States and European countries.

The Desert region of east Jordan, which accounts for nearly two - thirds of the total land area of the country, is the home of the Bedouins, whose ability to prosper in this harsh environment is legendary. Despite the extreme climate of this semi - arid desert region, the Bedouins raise sheep and goats for domestic consumption, as well as for export.

Table1.1: Agro - Climatological Zones in Jordan

Zone	Average Rainfall Mm	Area Thousand Hectare	Percent
Arid Desert	< 100	6925	77.53
Desert	100 - 200	1130	12.65
Marginal	200 - 300	389	4.36
Semi - arid	300 - 400	169	1.89
Semi - humid	400 - 500	125	1.40
Humid	> 500	94	1.05
The Jordan Valley	100 - 350	100	1.12

Source: Haddad, N. (1991)

Jordan, a small Arab country with population of about 5.1 million in year 2002 in the Middle East, is one country that has very limited water supply for competing uses in agriculture and human consumption. In fact, Jordan is also poor of other natural resources such as oil.

Jordan's population has been growing at a very high annual rate of 3.6 percent doubling the Jordanian population in 22 years. About 25 percent of the total population and one third of the poor live in rural areas (CBJ, 2004). Jordanian authorities stated that 21.3 percent of the Jordanian households were below the absolute poverty line of an annual per capita income of 140 JD in 1995. The rate of poverty in rural areas is higher by almost 30 percent compared to about 20 percent of Jordanians living under the poverty line in urban areas. In 2002, the average annual income per capita was 1,888 US$ (CBJ, 2004).

Rapid increases in population have placed unprecedented demands on water resources. In the mid-long term, with a growing population and an increasing water demand, Jordan will not be able to satisfy its increasing water demands from renewable water resources [(1)]. The increase of population in Jordan is one of the most affecting factors in the increasing demand on drinking water, which increases at high rates annually.

The average family size is 6.5 persons with a dense of 59.6 persons / one Sq.Km; this will affect the allotted water supplies per person, which we note became high, i.e. rose from 95.2 liters / person / day in 1985 to 126.5 liters / person / day in 2002, in spite of the increase of population (MWI, 2002).

[(1)] Renewable water resources: The long-term average annual of rivers (surface water) and recharge of aquifers (ground water) generated from precipitation. They are computed on the basis of the water cycle.

The majority 78 percent, of the population is concentrated in urban areas located in the northern governorates of Amman (Capital of Jordan), Zarqa, Irbid and Balqa. These areas are situated more than 1000 meters above Jordan's primary surface water resources coming from the Yarmouk and Jordan River Basins.

Jordan's population has been augmented by three population influxes: (1) Arab - Israeli war of 1948 (then 450,000 Palestinian refugees); (2) Arab - Israeli war of 1967 (then 400,000 displaced Palestinians); and (3) the returnees during the 1990 Gulf Crisis (then 300,000). Not surprisingly, the sudden waves of refugees and displaced persons provided no time for organized population settlement planning, and they all settled in or nearby these urban areas.

1.1 Rainfall

Rain is the main source of both surface and underground water. Generally, people gather around the water pouring areas [(2)], which provides a clear indicator that there is an inconsistent distribution of the population density in the kingdom as a result of the nature and conditions of the geographic area. This reflects the variations in the water needs by the population distribution as well as the services level as per the geographic areas.

The average rainfall quantities in Jordan amounted for about 8330.7 million cubic meters / year (MWI, 2002). Normally, about 85 percent of this quantity is lost in evaporation to the atmosphere, with the rest is sent to the rivers and valleys, shaping up the renewable ground water which account for about 4 percent of the total volume of the rainfall. Meanwhile, the surface water account for about 11 percent of the total volume of rain water (MWI, 2002).

[(2)] Water pouring areas: Water resources are available in these areas.

Subsequently, rain is the main source of water in the kingdom, which varies from year to year, which also, will affect the ground and the surface water reservoir, non - irrigated agriculture, pastures and animal wealth.

There are also other water sources not yet completely discovered and utilized, such as the historical underground, non-renewable water, and low quality water, whether the surface or ground (MOP, 1999).

Table 1.2 indicates the likelihood of the rehearsal of the annual rainfall average around the mean (8001 - 9000) million cubic meters / year was 0.2 during the past 65 years.

In the meantime, the likelihood of the below average rainfall is 0.43, which means dry, bad years. As for the above the average rainfall possibility, it is 0.37, which will be deemed good rain year. That is every 100 years there will be 20 years with medium, below average rainfall, 37 years over the average, i.e. good years. That is there will be 57 yeas of medium or slightly over medium average rainfall, the case that will generate water deficit to meet the increasing demands of water for various uses.

This, by necessity, calls for paying great attention to the water scarcity and the search for new water sources, considering the vital importance of water for the lives of the citizens from all life aspects, economical, social, environmental, and health... etc. Water, then, is the life component.

The rainfall variation is shown by measuring the variation of the coefficient of the rainfall quantities which amounted 31.63 percent, as shown in Table 1.2. The more the value is, the more the quantities of the rainfall are dispersed, and being distanced from the long-term average. Conversely, the less the value is, the more is the evident that the quantities of the rainfall are around their long- term annual average.

Table 1.2: The Likelihood of the Rehearsal of the Annual Rainfall Average during (1937 - 2002)

Rainfall Intervals (MCM)	Frequency (F)	Accumulative Frequency	Likelihood
(2001 - 3000)	1	1	0.015
(3001 - 4000)	2	3	0.031
(4001 - 5000)	3	6	0.047
(5001 - 6000)	8	14	0.123
(6001 - 7000)	6	20	0.092
(7001 - 8000)	8	28	0.123
(8001 - 9000)	13	41	0.200
(9001 - 10000)	8	49	0.123
(10001 - 11000)	9	58	0.138
(11001 - 12000)	4	62	0.062
(12001 - 13000)	1	63	0.015
(13001 - 14000)	1	64	0.015
(> 14001)	1	65	0.015
Total	65	65	1.00
Coefficient of variation (c.v) for the rainfall during 65 years = 31.63 %, (standard deviation (s.d) of rainfall = 2635 mcm divided by average rainfall = 8330.7 mcm)			

Source: Calculated from MWI (Annual Reports, 1980 - 2002), DOS (Statistical Year Book, 1980 - 2002) and DOM (Annual Bulletins, 1980 - 2002) and Data Files from these Sources for different years

Table 1.3 indicates the percentage of the sizes of rain falling on all the water basins of the kingdom as per the water years 1994 - 2002. It is clear that the highest quantities on the water basins were during the 1997 / 1998 water year 107 percent of the long - range average.

The lowest quantity was during the water year 1998 / 1999, with a rainfall average of 35.2 percent of the annual long-range average, when there were three years with an average was equal or more than the rainfall long-range average, representing 37 percent of the total period.

That is 63 percent of the total period was characterized by that the long - range waterfall is less than the average, the matter that implies a strong likelihood that Jordan will witness drought periods.

1.1.1 Seasonal Rainfall Distribution

Rain is the base of water wealth in Jordan. But, what complicates the water issue is the heavy variation in the rainfall from one month to another, as shown in Table 1.4.

Rainfall is centered on certain months such as January, which represents 0.278 of the total rains; it may be accompanied by snow. It is less than that of January in the other months. This problem has negative reflections on the agricultural production, and subsequently on the increasing needs for household water, which necessitates the increase of water supply during the months with low or no rains.

Table 1.3: The Percentage of the Sizes of Rain Falling on all of the Water Basins of the Kingdom as per the Water Years (1994 - 2002)

Rainfall / Years	Water Years							
	94 / 95	95 / 96	96 / 97	97 / 98	98 / 99	99 / 2000	2000 / 2001	2001 / 2002
Total of Rainfall (MCM)	8524	6046	8746	9110	2972.8	3651.1	7375.3	7545
Long - Range Average (MCM)	8561.3	8519	8519	8529	8441.4	8453.7	8436	8330.7
% From Long – Range Avg.	99.6	71	103	107	35.2	43.2	87.4	90.6

Source: Department of Statistics (1995 - 2002), Ministry of Water and Irrigation (1995 - 2002)

Table 1.4: Rainfall per month on the Kingdom during (1994 - 2002) MCM / Month

Months	Years									Average	Seasonal Rainfall Index
	1994	1995	1996	1997	1998	1999	2000	2001	2002		
Dec.	2907.1	169.6	2298	2125	1978.2	930.6	2845.7	1222.6	2990.3	1940.8	0.278
Feb.	1211.2	1516.1	445.4	2490.3	1004.9	1276.7	806.6	1174.2	919.6	1205	0.172
Mar.	1267	449.3	2202.1	1523.8	1706	378.3	893	260.8	1273.7	1106	0.158
Apr.	90.5	309.1	193	157.9	145.2	189.7	10.8	492.3	685.4	202.7	0.036
May.	13.2	23.1	1.4	101	75.3	0.6	....	505.4	35.4	83.9	0.012
Jun.	2.5	....	....	....	....	....	....	....	....	0.28	0.0000
Jul.	....	....	3.8	....	....	....	0.1	....	....	0.42	0.0001
Aug.	....	....	....	....	....	....	....	....	....	....	....
Sep.	64.3	0.2	....	24.4	6.8	....	4.9	....	11.8	12.5	0.002
Oct.	536.1	14.6	367.4	514.7	12.8	32.8	536.9	100.7	268.4	264.9	0.038
Nov.	3716.6	549.2	542.7	604.2	29.7	37.5	98.9	856.3	593	780.9	0.112
Jan.	2401.9	438.6	850.2	1739.6	239.7	216.8	1671.1	1410.3	3088.5	1339.6	0.192
Total	12210	3469.8	6904	9280.9	5198.6	3063	6868	6022.6	9866.1	6987	1.000

Source: DOM, Annual Bulletins, (1994 - 2002).

1.2 The Issues

Water scarcity is a great threat to the global sustainability of the water supply, potentially to world peace and development. It will be the main problem for future generations and have effects in many parts of the world. The scarcity will affect mostly the population and all the main sectors of the economy (Household, Industry and Agriculture); in addition to undermine the economic, social and environmental foundations of many developing countries (Hamdy, 2000).

Providing and distributing water resources had been a serious issue for all decision makers and strategy planners. There had always been an imbalance in demand and supply of water. This concern is felt across all the countries. Therefore, each country needs to define its priorities. In fact, increasingly more economic sectors demand higher allocation of water, thus, creating intense competition among the user sectors.

Arab World (3) is a clear model for this defect, where more than 70 percent or about 247 b.c.m. of Arab World's water comes from outside the Arab region. While the total Arab World area is more than 10 percent of the World area, the water resources ratio is less than 0.6 percent of the international available water resources. This shows the smallness of quantity available for Arab citizen as compared to its counterparts in Europe, America and Africa (FAO, 1994 and 1997).

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(3) Arab World stretches from the Atlantic Ocean in the west to the Persian Gulf in the east, and from the Mediterranean Sea in the north to Central Africa and the Indian Ocean in the south, consisting of 22 countries. The countries: Algeria, Iraq, Mauritania, Saudi Arabia, United Arab Emirates, Bahrain, Jordan, Morocco, Somalia, Comoros, Kuwait, Oman, Sudan, Djibouti, Lebanon, Palestine, Syria, Egypt, Libya, Qatar, Tunisia and Yemen.

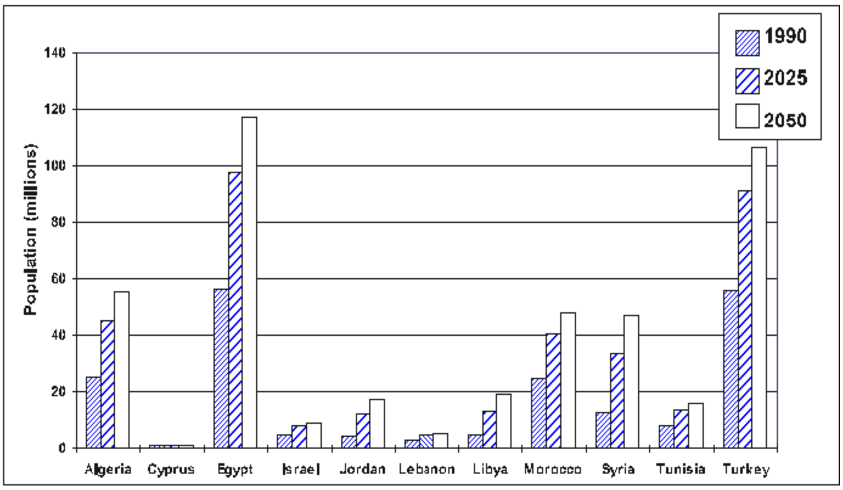
According to the international organizations, especially the FAO, the World Bank and the United Nation, the current trends indicate an approaching water crisis in several regions, most notably in the Middle East and North Africa, as well as an increasingly large number of other countries worldwide (FAO, 1997, World Bank, 2001 and United Nation 1992, 1997). The main constraint to agricultural development of land in the Mediterranean will be the availability of water, rather than land. Although the availability of water to each country remains constant, the demand for it will increase steadily in the foreseeable future. The major challenge facing water planners and managers in the future will be to balance demand and supply of water.

In the southern arid and semi-arid countries of the Mediterranean, water is scarce, often of poor quality, vulnerable to pollution, sometimes a non - renewable resource, and harmful to the soil. The region needs feasible and realistic water management strategies to deal with safeguarding water to meet basic needs for various uses and allocating scarce water for socioeconomic development. At the moment, the policies, institutions and planning procedures in place to manage water are not well suited to these tasks (Hamdy, 2000).

The total population of Mediterranean countries is around 360 million, as shown in Figure1.1, but will reach between 520 and 570 million in 2025. The rate of this high population growth is an average of 3 percent yearly in southern countries (Jordan is one of them), and this alone can be expected to increase the total water requirements. However, past experience indicates that per capita water requirements also increases with standards of living (UN–PD, 1994). Rapid population growth is always linked to fast urbanization. Urban growth will be explosive in the southern and eastern countries, where it has been, on average, five times faster than in 19th - Century Europe.

Growth rate is not the only factor to consider. Urban populations will be very large: 200 million more inhabitants in 2025 in the areas south and east of the basin, that is, as much as the total urban population of the Mediterranean region at present. The urban population of the Mediterranean basin could, in fact, number between 380 and 440 million, compared with a little more than 200 million today. Although the annual growth rate of urbanization is high in the Mediterranean region in general, it is much higher in the south of the region 4.5 percent than in the north 2.8 percent (UN – PD, 1994).

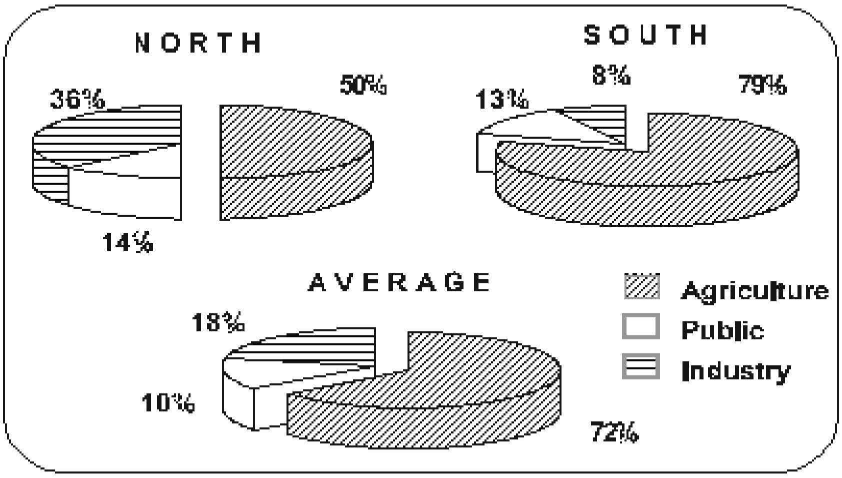
Under such conditions, southern and eastern Mediterranean countries will find it difficult to be self-sufficient in meeting their needs for agricultural, domestic, and industrial water. One of the most critical challenges will be to supply drinking water to urban areas.



Source: UN – PD, (1994).

Figure 1.1: Population Growth in Southern Mediterranean Countries (1990 - 2050)

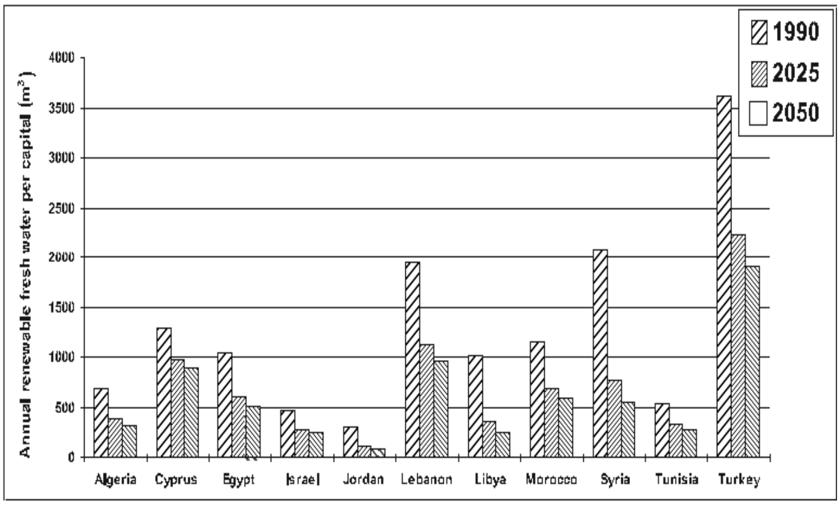
Countries in the Mediterranean as a whole use 72 percent of their water resources for irrigation, 10 percent for drinking and 16 percent for industry. But northern Mediterranean countries make completely different uses of water than in the south, as shown in Figure 1.2.



Source: Elaboration on LAMBED World Resource Institute Data, 1985 (WRI – IIED, 1985)

Figure 1.2: Water Use in Mediterranean Countries

The development of urban centers around the basin means that the water supply can break down when drought persists. Per capita availability of water, as shown in Figure 1.3, is the true measure of water scarcity in the region; Jordan is considered the poorest country in water according to the World Bank studies in 1993, 1997 and 2001.



Source: UN – PD, (1994).

Figure 1.3: Available Fresh Water per capita* in Southern Mediterranean Countries (1990 - 2050)

* Note: 1700 m^3 = Periodic Water Stress; 1000 m^3 = Chronic Water Stress; 500 m^3 = Absolute Water Stress.

In several Mediterranean countries, an imbalance (Water Demand and Water Supply) have started to appear around 2000. The water demands of southern Mediterranean countries - Jordan one of them - will have fast approached resource limits, and the majority of these countries may have entered into a period of chronic shortage during the 1990s. These countries will be facing several similar problems, outlined as follows: declining water resources per inhabitant, both in terms of availability and withdrawals; available water per capita will fall by nearly 50 percent.

Excessive reduction in water withdrawals per capita will significantly impact water use, creating notable competition and conflict between users in various sectors, especially in the irrigation and domestic sectors; countries will give priority to satisfying the demand for drinking water over that for irrigation, this will cause less irrigated land and more land degradation, as a result.

A flurry of international activity in recent years has called attention to the problem of water scarcity and the need for action to solve it. Agenda 21, the global action plan that emerged from the 1992 Earth Summit in Rio de Janeiro, and the World Bank's 1993 water - resources policy paper put helpful guiding principles and spawned a variety of national studies. The United Nations Commission on Sustainable Development requested a global freshwater assessment and the study team reported to the United Nations General Assembly in 1997. Most nations have not realistically assessed how limited water supplies will affect their food production and economic prospects. They need to set priorities and make trade - offs (World Bank, 1993 and United Nations, 1992, 1997).

One of the lessons learned over the past decade is that technical solutions alone cannot provide the increasing population of the region with safe water supply and proper environmental sanitation. The region needs to integrate the technical, institutional, managerial, social, and economic aspects of water-resources management. The new approach for sustainable water supply and sanitation depends on local involvement, solutions, and knowledge within an overall framework of water and natural resources planning.

The future requires new mechanisms to protect the region's water resources and allocate diminishing supplies for increasing and competing uses. Anticipatory and preventive approaches would help in managing the quality and quantity of water in arid regions while acknowledging it's social, economic, and environmental aspects (United Nations, 1992).

Collection, processing, and analysis of good quality data on the quantity and quality of surface water and groundwater resources are vital in planning to meet water demands. The quantities of water available to communities in dry lands and the safe output from the aquifers are key factors in long-term sustainable development and the war on desertification. Equally important is information on water, particularly data on water abstraction and consumption for various purposes, as well as data on wastewater discharge. Researchers must intensify their efforts to gather, organize appropriately and disseminate fundamental water data. Data management is a main issue, essential in reliably predicting water supplies and formulating allocation strategies.

The problem of water resources and efficient management is at the heart of the common concerns of the Mediterranean countries, today. Chapter XVIII of Agenda MED 21, the Mediterranean version of Agenda 21 adopted by the United Nations Conference on Environment and Development, emphasizes that all Mediterranean countries should have prospective studies, “to anticipate medium and long-term development in countries already facing sharp water shortages and recommended solutions likely to reduce their effects” (United Nations, 1992).

Mediterranean Action Plan-phase II, by broadening its objectives within the framework of the revised Barcelona Convention adopted in 1995 included among its priorities the management of water resources for sustainable use. Attenuation or adaptation of water demand can help supply meet demands to a large extent. The awareness of this fact makes water demand management a very topical issue to be studied (United Nations, 1997).

Mediterranean countries need a new management approach to overcome the challenges between water users and attain sustainable sectorial water use: This should lead to review water uses and the various tools to promote more desirable levels and patterns of use. It should incorporate aspects of conservation and efficient use essential to achieve a reasonable balance between demand and supply.

Countries in the region should concentrate on water demand management in the agricultural sector, as irrigation takes the highest share 80 percent of water use and the agricultural sector could supply most of the water savings needed to meet the growing water demand in the municipal and industrial sectors. Water demand management of irrigated agriculture would be the bedrock of sustainable water use in the region (Hamdy, 2000 and United Nations, 1992).

For example, irrigated agriculture in Jordan - irrigation takes the highest share about an average 70 percent of total water, over the period 1991 - 2000, (MWI, 1991 - 2002) - will first and disproportionably be affected by the increase of water scarcity and the grow of demand in other sectors that would cause agriculture to compete with higher value uses.

The agricultural sector in Jordan relies on more efficient use of water, changes in the agricultural production practices and reduction of waste. Adequate water demand management in the agriculture sector requires improving irrigation water demand management through better farm water management systems, which should include reducing distribution losses, changing cropping patterns, improving scheduling and adopting more efficient technologies. In addition, farmers should be encouraged in making efficient use of water and innovative water saving technologies, which would improve economic returns on irrigation.

Jordan represents the most difficult model and is the best representational state of the poorest countries in water in the World. The disorder of the balance equation between the demand and the supply of water is shown by the share of the Jordanian individual that does not exceed 15 percent out of the international water poverty line level (World Bank, 1997). The water sources inability to respond to the increasing needs of the population and the different sectors; and the increase of the inability parallel to the development that Jordan witnesses in all fields have made the international organizations especially the World Bank classifies Jordan as one of the poorest countries in water in the World.

Due to the importance of water and sectors related to it in Jordan as well as the several problems have being faced particularly, the scarcity. Jordanian government is very concerned putting the priorities to solve the problems and find suitable solutions to this vital sector.

This study comes in the same context where it clarifies in general the water situation of the different sectors in Jordan, specifically the irrigation sector in more detail through an analysis of the available data to find out the suitable solutions to the problems of this important sector.

1.3 A Major Problems of Jordan's Agriculture and Water

The agriculture sector's contribution in Gross National Product is less than 2.25 percent in 2001 (DOS, 2001). In order to maintain an effective balance in water supply and demand importation of food grains and energy must be increased. Widespread water shortages in Jordan have made the urban water problem a central policy issue. The government directed all concerned agencies to develop a short, medium and long-term strategy for addressing the impending water crisis. Water availability compared to the levels of demand for water is increasing.

Gap exists between water supply and demand that is evidently growing with time by virtue of population growth, improved living standards and other factors embodied in the demand function of water. The supply side will be affected by permanent or temporal loss of certain water resources, especially groundwater reservoirs, due to over-extraction, over-exploration, environmental degradation and mismanagement of utilization. Policies adopted to bridge the gap between supply and demand are fundamental to the approach to water resource management. The determination of the gap between the supply and the demands for basic needs requires the calculation of both sides of the supply and demand equation.

The difference between supply and requirements is likely to decrease in the current decade, assuming that all planned projects go on as conceived. Therefore, it is expected to increase. Thus, the water deficit in Jordan will continue to be challenging issues. Furthermore, the assumption that all projects will be implemented as planned may be unrealistic, as donor financing has yet been secured for only about 42 percent of the total volume of the investment program and government and private sector financing is unlikely to make up for the difference (MWI, 1997 d). If some of the major bulk supply projects mentioned above is delayed, the water deficit is bound to increase beyond the projected values, placing additional stress on all uses. Drinking water needs will face shortfalls, but since such needs are given top priority in the government's policy, water availability for agricultural use could face the maximum constraints.

The current "virtual water" [(4)] imported, according to estimates of Ministry of Water and Irrigation (MWI, 2002), is about 6.0 billion cubic meters per year. This is approximately seven times Jordan's annual water budget and 10 times Jordan's renewable water supply (El-Naser, 1999).

[(4)] "Virtual water" represents the amount of water needed to raise a certain quantity of food. In other words, a ton of grain has 1 ton of "virtual water" embedded in it because that is how much water it took to raise that amount of grain. The concept of "virtual water" is powerful in two senses. First it provides the remedy for progressive and occasional local "agricultural" drought. Agricultural drought is the form of drought, which is most common as deficiencies in soil water are evident in the failure of crops.

For several years, renewable ground water resources have been withdrawn at an unsustainable rate. In addition, surface and ground water quality in some areas is deteriorating. Since 1985, Jordan's annual water budget has increased from approximately 639 MCM to approximately 850 MCM in 2000, (MWI, 1998 - 2000).

From 1992 through 1994, the annual water budget exceeded 900 MCM, peaking at 984 MCM in 1993. During these years Jordan was blessed with extremely wet winters and water was more available to meet demand. Beginning in 1988, however, rationing of the water supply was initiated; Municipal water now is supplied according to a preset program. Municipal supply shortages varied from 6.7 MCM in 1986 to 51 MCM in 1994. By 1996, Jordan had begun to receive some regional waters specified in the 1994 Peace Treaty and the municipal shortage in 2000 is estimated at 32 MCM.

The use of modern irrigation techniques like drip irrigation, together with micro sprinklers and other water-saving devices has become widespread in Jordan, resulting in substantial water savings. Extensive water savings have also been realized through careful implementation of a variety of on-farm irrigation management practices.

Population growth and increasing demand for water for other uses are leading to rapid mining of aquifers, water shortages, competition, and conflict and the efforts for developing new water supplies to meet increasing demands, given limited financial resources, escalating construction costs, and rising environmental opposition.

According to Kneese and Sweeny (1985), water problem arises when water is not found in proper quantity and quality at the appropriate place and time. Water scarcity is the single most important natural constraint to Jordan's economic growth and development. Rapid increases in population and industrial development have placed unprecedented demands on water resources; Jordan's population has approached 5.0 million in 2002 and growing at a very high annual rate of 3.6 percent (DOS and CBJ, 2002). Total demand is approaching one billion cubic meters per year, which approximates the limit of Jordan's renewable and economically developable water resources.

Traditionally the government has played a dominant role in managing water resources, but with inefficient use of water, poor cost recovery for operating and maintenance expenses. There is the lack of coordination among the different parties that are related to the mechanism of allocating water for the different purposes as domestic, irrigation and industrial. That resulted in inefficient allocation of water and failure to place a high economic value on water.

The increasing cost of developing new water sources, and problems with the quality of service in agency-managed systems has led to a search for alternatives that make water allocation and management more efficient. In the mid to long - term, with a growing population and an increasing water demand, Jordan will not be able to satisfy its increasing water demands from renewable water resources.

Meeting Jordan's future water demands, including delivery to major consumption centers, will require implementation of expensive development and conveyance projects. These projects will place a heavy burden on the national budget and will affect the national economy adversely. Financial constraints as well as the political difficulties of managing water demands clearly indicate that future water strategies must be selected carefully.

1.4 Water Resources

Jordan is facing a future of very limited water resources - among the lowest in the world on a per capita basis. Available water resources per capita are falling as a result of population growth. They are projected to decline from more than 170 m^3 / capita / year (all uses) at present to only 91 m^3 / capita / year by 2025, putting Jordan in the category of having an absolute water shortage (World Bank, 1997). Current water use already exceeds the renewable water supply. The annual water deficit has been satisfied by the unsustainable practice of overdrawing highland aquifers resulting in lowered water tables and declining water quality.

Jordan's water resources consist primarily of surface and ground water. Renewable water resources are estimated at about 780 million cubic meters (MCM) per annum, including ground water; 275 MCM / year distributed among 11 basins and usable surface water; 505 MCM / year distributed among 15 catchments basins. An additional 143 MCM / year of ground water are estimated to be available from fossil aquifers. Brackish aquifers are not yet fully explored, but at lowest 50 MCM / year is expected to be available for urban uses after desalination (JICA, 1995).

Treated wastewaters are being used on an increasing scale for irrigation, primarily in the Jordan River Valley, and can provide at lowest an additional 80 MCM / year until the year 2010 (El-Naser and Elias, 1993).

Ground water is the major source of water supply in the country. Jordan's water budget for 2000 was approximately 817 MCM, of which more than 474 MCM was provided from ground water sources; 412 MCM from renewable, 62 MCM from non-renewable, as shown in Table 1.5. The total annual recharge of ground water in Jordan is approximately 275 MCM; consequently, about 138 MCM / year was over pumped from ground water resources in 1997 and more in 2000.

Surface water contributed approximately 33 percent or 272 MCM to the 2000 water budget. Approximately 72 MCM of wastewaters were reused in 2000; 9 percent of the water budget. In the last decade, treated wastewater has become an important water resource for restricted uses and has been actively incorporated into the strategic planning of water policy makers in the country.

Table 1.5: Water Sources and Water Uses in 2000

Source	Uses in Million Cubic Meters (MCM)				Total Uses
	Municipal	Industrial	Irrigation	Live-stock	
1. Surface Water	53.309	2.537	209.670	6.000	271.516
- Jordan Rift Valley	38.464	2.537	121.180	0.000	162.181
- Springs	14.845	0.000	38.000	0.000	52.845
- Base & Flood	0.000	0.000	50.490	6.000	56.490
2. Ground Water	185.735	34.156	252.300	1.413	473.604
- Renewable	176.362	29.586	204.644	1.409	412.001
- Nonrenewable	9.373	4.570	47.656	0.004	61.603
3. Treated Wastewater	0.000	0.000	72.033	0.000	72.033
- Registered	0.000	0.000	66.933	0.000	66.933
- Not Registered	0.000	0.000	5.100	0.000	5.100
Total	239.004	36.693	534.003	7.413	817.153

Source: MWI, (1998 - 2000), the 1998 - 2000 Water Budget

1.4.1 Surface Water

Jordan has been divided into 15 surface water drainage basins, as shown in Figure 1.4 and Table 1.6. Surface water discharges in the country's basins greatly vary among the seasons and from year to year.

The collective long - term average base flow for all basins is about 519 MCM / year, the flood flow is about 327 MCM / year and the total flow about 846 MCM / year. The Yarmouk River Basin is Jordan’s greatest source of surface water and contributes approximately 40 percent of the annual total. This includes water flowing from Syrian territories within the Yarmouk Basin

1.4.2 Ground Water

Ground water is the major water resource in Jordan; it is the only water resource in some areas of Jordan. Ground water resources may be renewable or nonrenewable. Twelve (12) ground water basins have been identified in Jordan, as shown in Table 1.7 and Figure 1.5. Most basins are comprised of several ground water aquifer systems, as listed in Table 1.7. Approximately 80 percent of Jordan's known ground water reserves are contained in three main aquifer systems: (1) Amman / Wadi El Sir (B2/A7); (2) Basalt (Ba); and (3) Ram (formerly Disi). The total annual recharge to the ground water aquifers in Jordan is approximately 275 MCM.

Most renewable ground water resources presently are exploited to their maximum capacity. In some cases abstraction exceeds the safe yield of the aquifer system. About 138 MCM / year were over pumped from ground water resources in 1997. In recent years, over pumping have exceeded 200 MCM / year. Today, aquifers in seven ground water basins are being over pumped with abstractions ranging from 135 to 225 percent of the safe yields (El-Naser et al., 1998). In four basins abstractions equal the safe yield.